Best Practices for Taking Face Photographs and Face Image Quality Metrics

NIST Biometric Quality Workshop

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Motivation and Outline

- **Motivation for face image quality measurement:**
  - **U.S. Department of State using automated face recognition for Nonimmigrant, Immigrant, and Diversity Visa application processing**
  - **Ensure accurate automated and manual face recognition**
- **Through ISO/IEC JTC1 SC37, proposed adding a best practices Annex to ISO 19794-5** (Information Technology — Biometric Interchange Formats — Part 5: Face Image Data)
- **Nature of problem - how should we measure face image quality?**
  - **Using test patterns**
  - **Using face images and face image quality metrics**

Some Examples of Problems

Improper color

Too dark

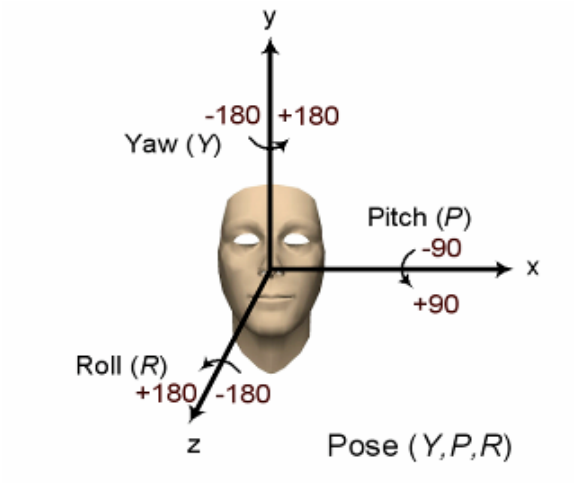
Contrast too high

Over-exposed

Shadows on face

Shadow on background

Amendment to Add Best Practices Annex to ISO 19794-5



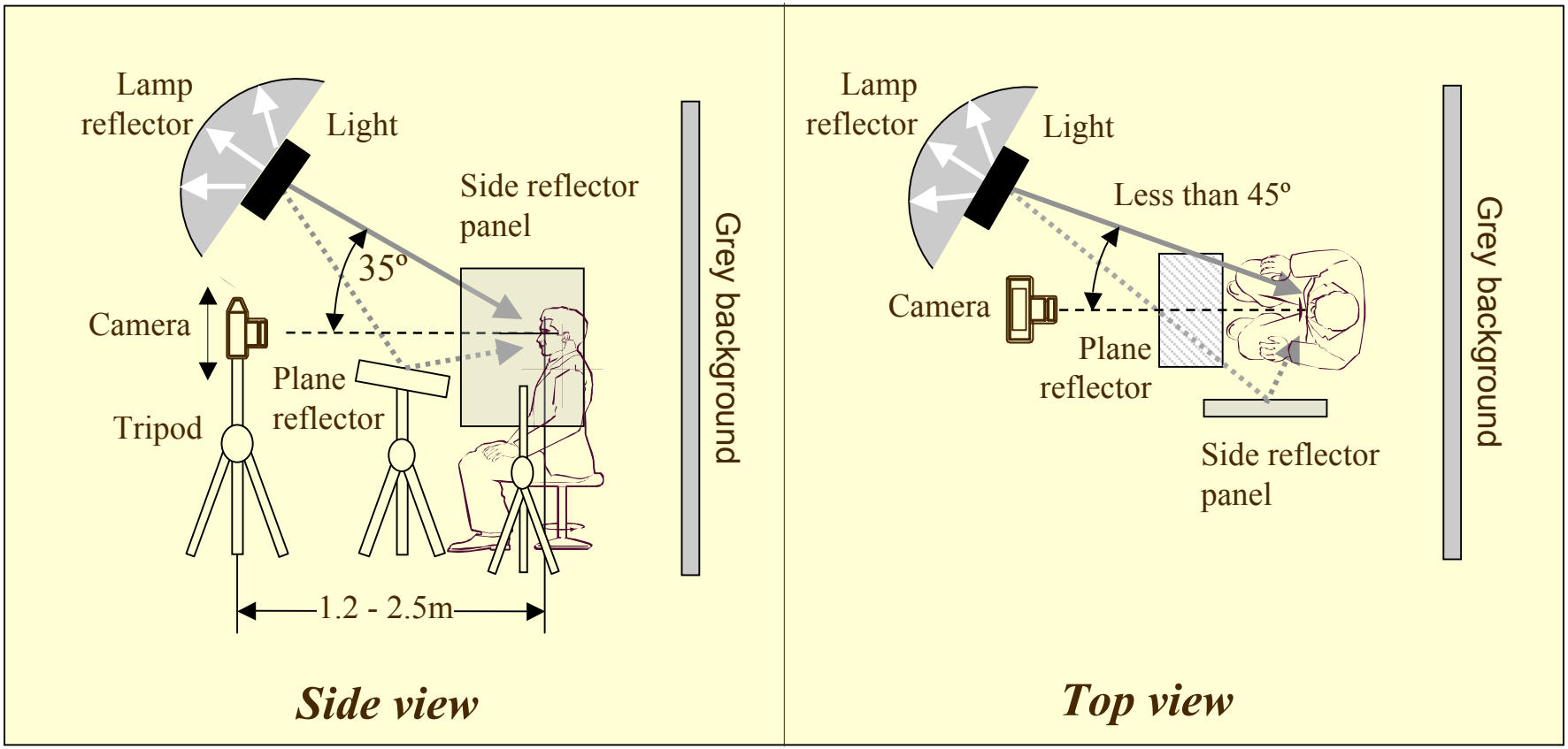
AMENDMENT 1, *Conditions for Taking Photographs for Face Image Data*

Editor: Tetsuo (Ted) Tomonaga of Japan
Co-editor: Donald D'Amato

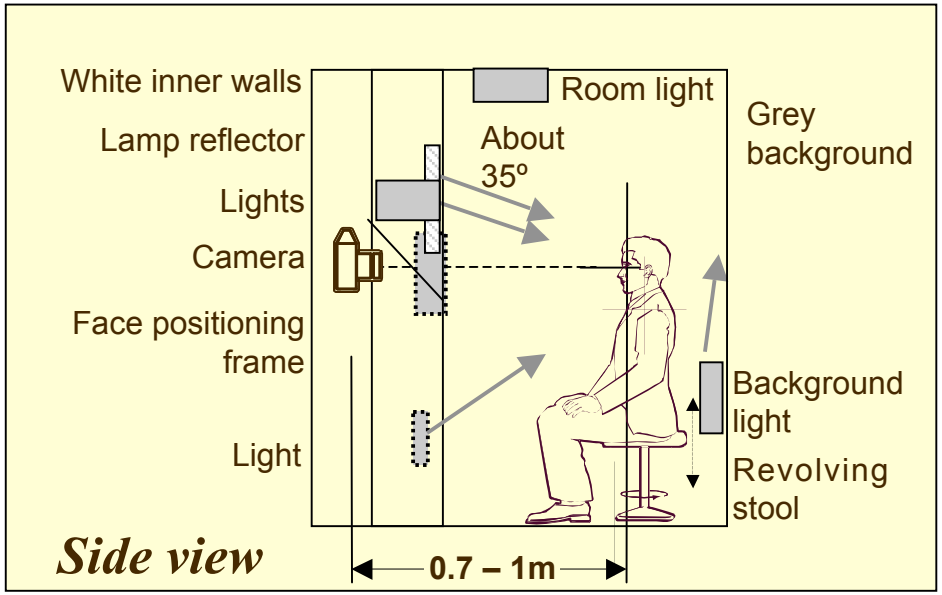
Circulated to ISO/IEC JTC1 SC 37 National Bodies for PDAM ballot, with due date of 5-28-2006

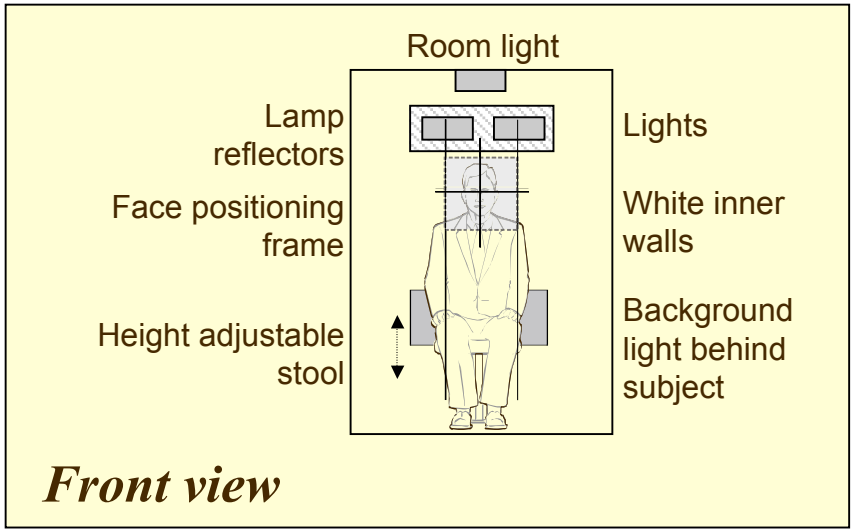
- Provides explicit guidance for the design of photographic studios and photo booths
- Supplements information provided in the standard and existing Annex A
- Provides guidance on printing quality and on scanning printed face photographs

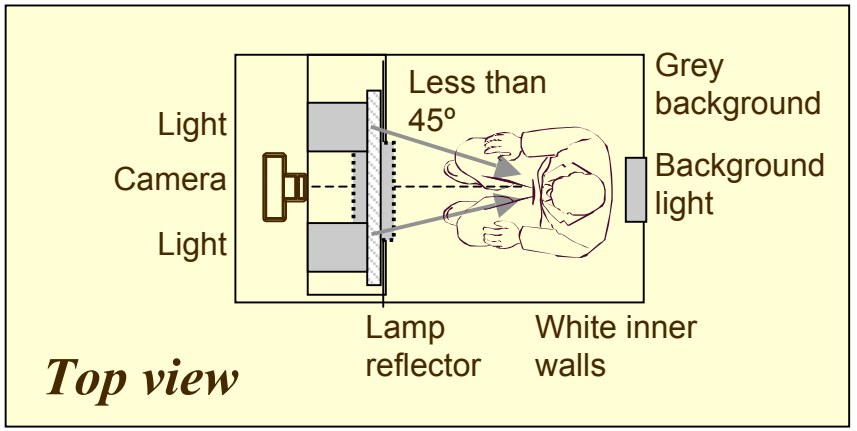
Single Lamp Arrangement for a Photo Studio



Lighting and Camera Arrangement for a Photo Booth





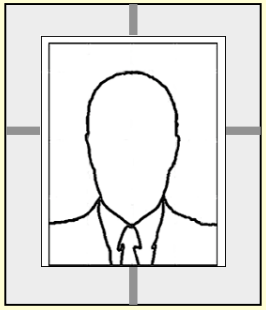


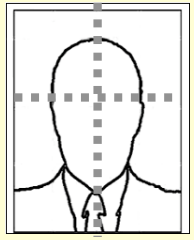
User Interface: Head Positioning Frame

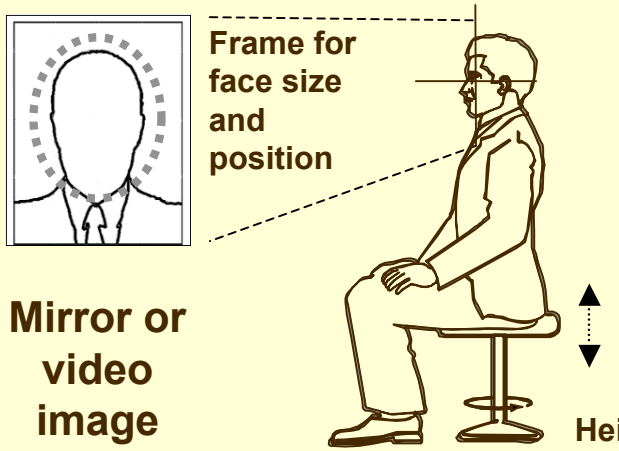
Confirming position frame example 1: Outer indicator lines

Confirming position frame example 2: Inner indicator lines

Confirming position frame example 3: Inner indicator frame







Evenness of Illumination

Two lights and a background light	Single light and a side reflector panel	Single light (without a side reflector panel) [NR]
		
Left-Right ΔEV=0.2		Left-Right ΔEV=1.5

$$\text{Exposure Value}: \ \text{EV} = Log_2\left(\frac{\text{F}^2}{\text{T}}\right) = 2Log_2(\text{F}) - Log_2(\text{T})$$

NR: Not recommended

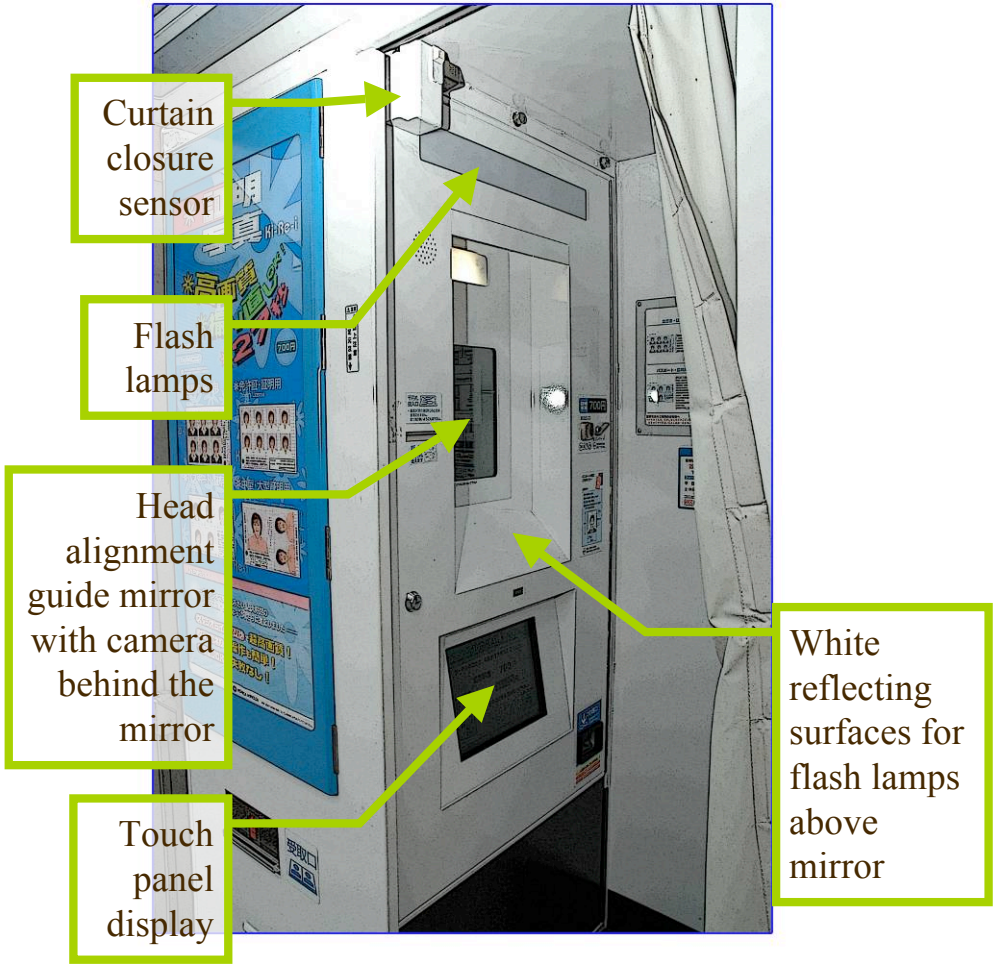
Effect of Using On-Camera Flash

Single Lamp with Reflector Panel	Camera Flash Only [NR]
	

Note glare on glasses & specular reflections from face, deep shadow on background–blending with dark hair

NR: Not recommended

Example of a Photo Booth



Example of a Photo Booth

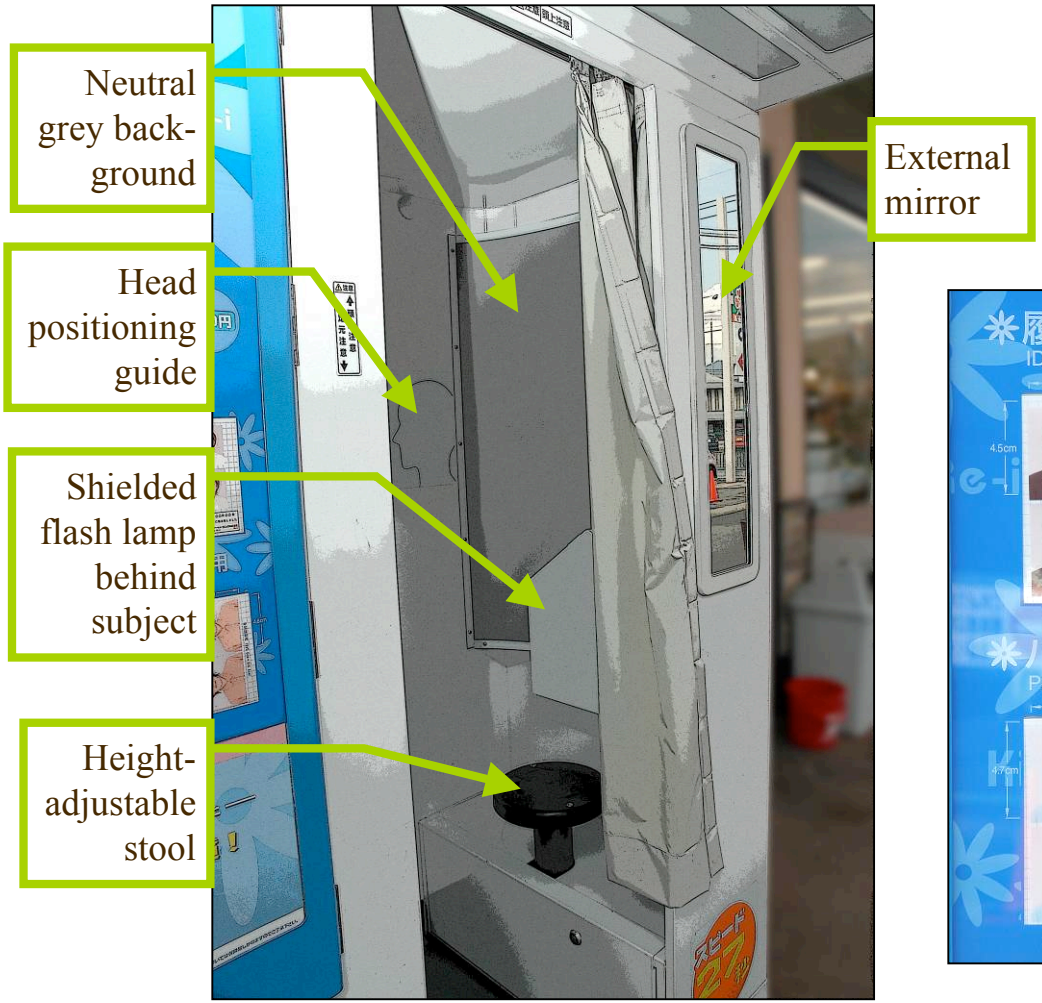
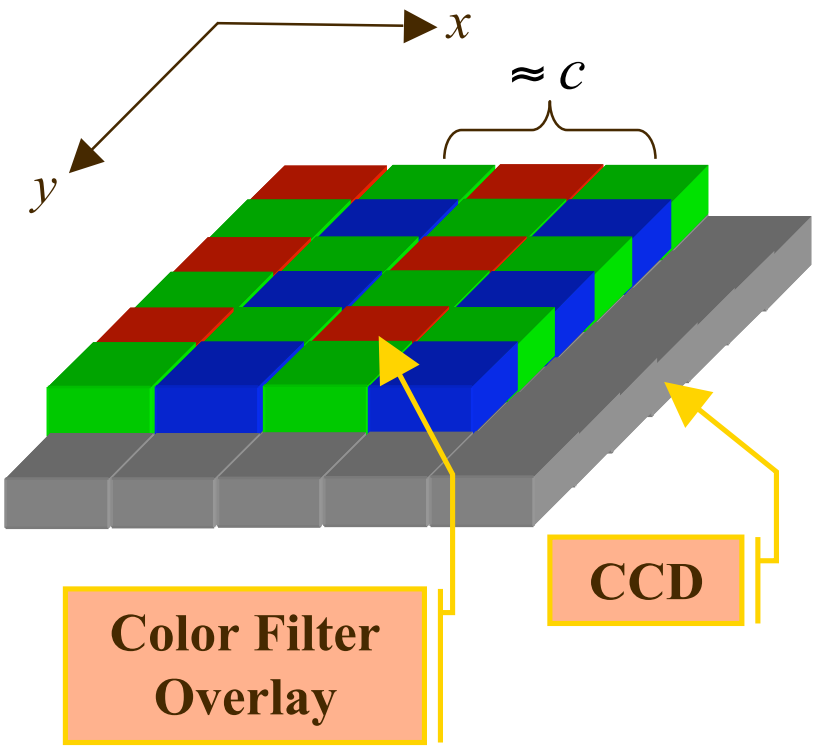


Image Quality Measurements

- Use test targets to calibrate camera (or scanner) and measure its characteristics
  - See http://www.i3a.org/downloads_iso_tools.html
  - Opto-electronic conversion function (OECF) – ISO 14524
  - Spatial frequency response (SFR) – ISO 12233 or ISO 16067-1
  - Noise measurements - ISO 15739
  - Color profile – See www.color.org
- Measure compliance of face images with specifications in ISO 19794-5

Color CCD Using a Typical Bayer* Pattern

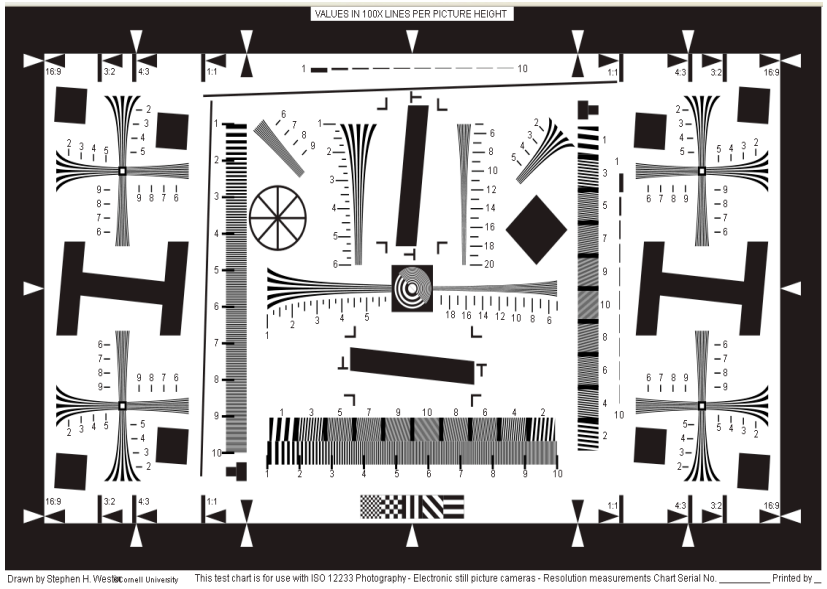


- CCD color imaging array
  - ½ of the elements are green
  - ¼ are red
  - ¼ are blue
- RGB values assigned by interpolation
- Overlay also filters out infrared, realigns the light, and provides a low-pass, anti-aliasing filter

* Bryce E. Bayer, Kodak researcher, awarded U.S. Patent #3,971,065, July 20, 1976

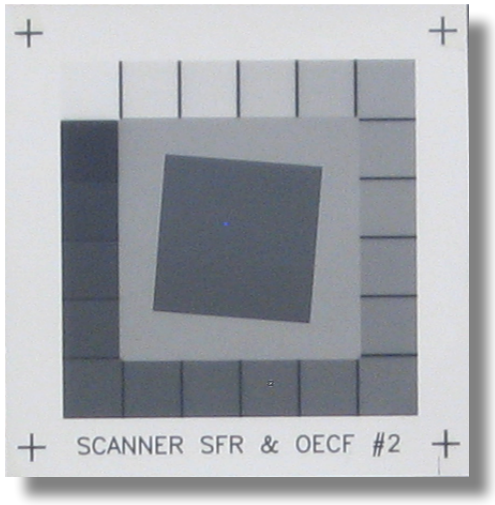
Test Chart for Spatial Resolution Measurement: ISO 12233

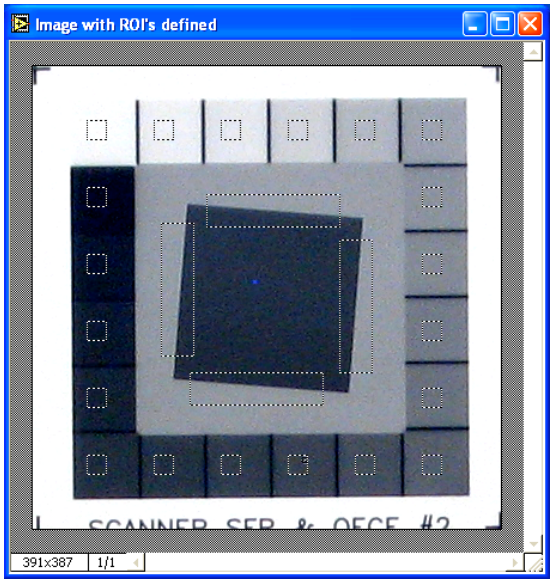
- Contains many visual indicators of spatial resolution
- Slanted edge targets provide:
  - Oversampling of the edges – edge position resolved to better than a single pixel
  - High-resolution measure-ment of the edge-spread function (ESF)

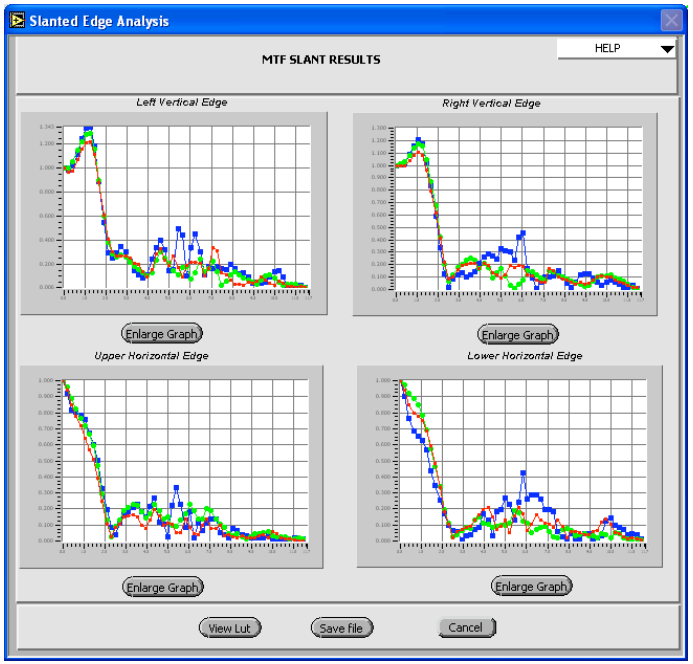


  - Noise reduction of the Line Spread Function (LSF) or differentiated ESF
  - Modulation Transfer Function (MTF) through the Fourier transform of the LSF

Slanted Knife Edge (Rotated Square) Target and MTF Measurement Software



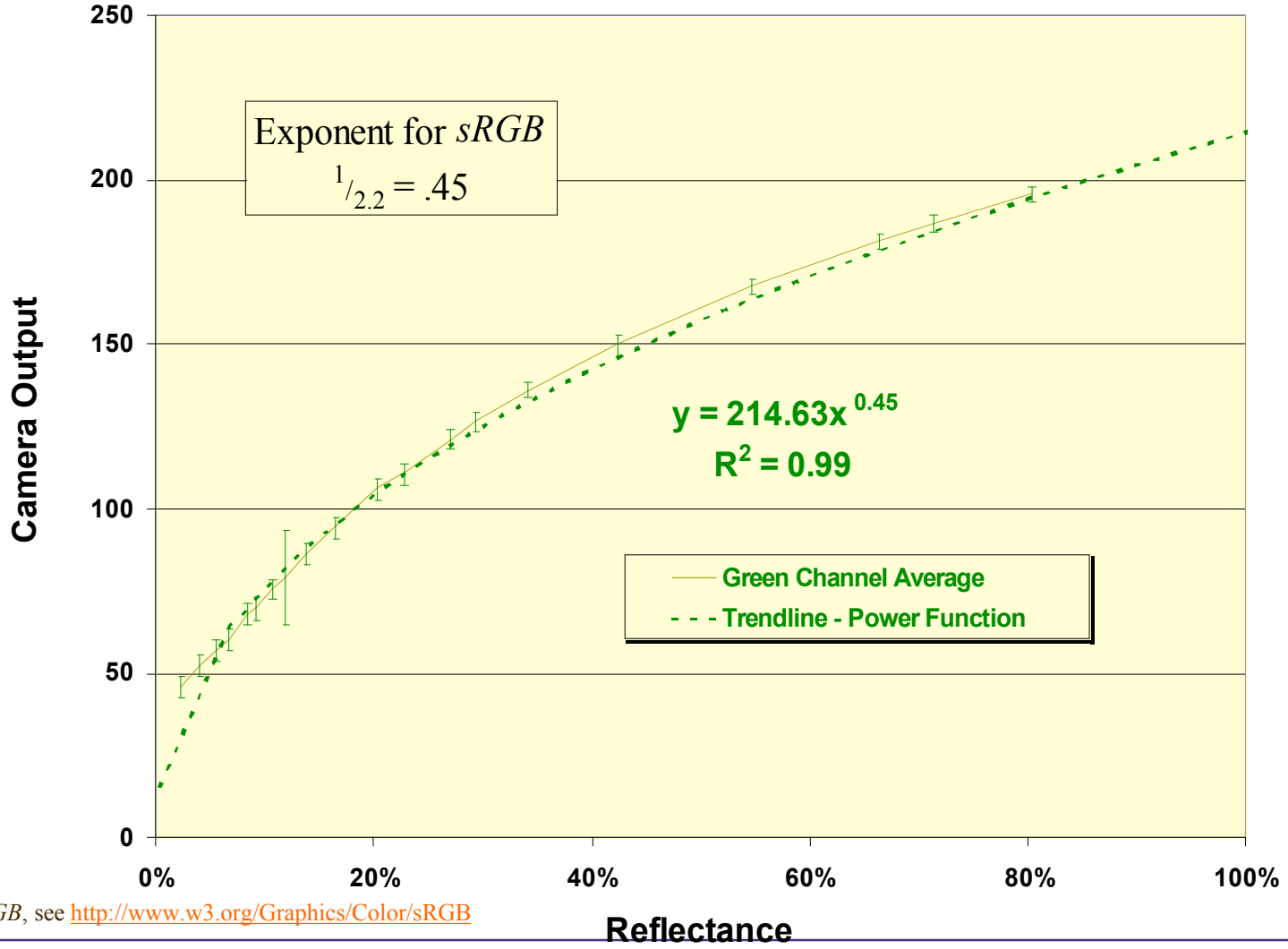




ISO 16067-1, *Photography - Electronic scanners for photographic images – Spatial resolution measurements – Part 1: Scanners for reflective media*

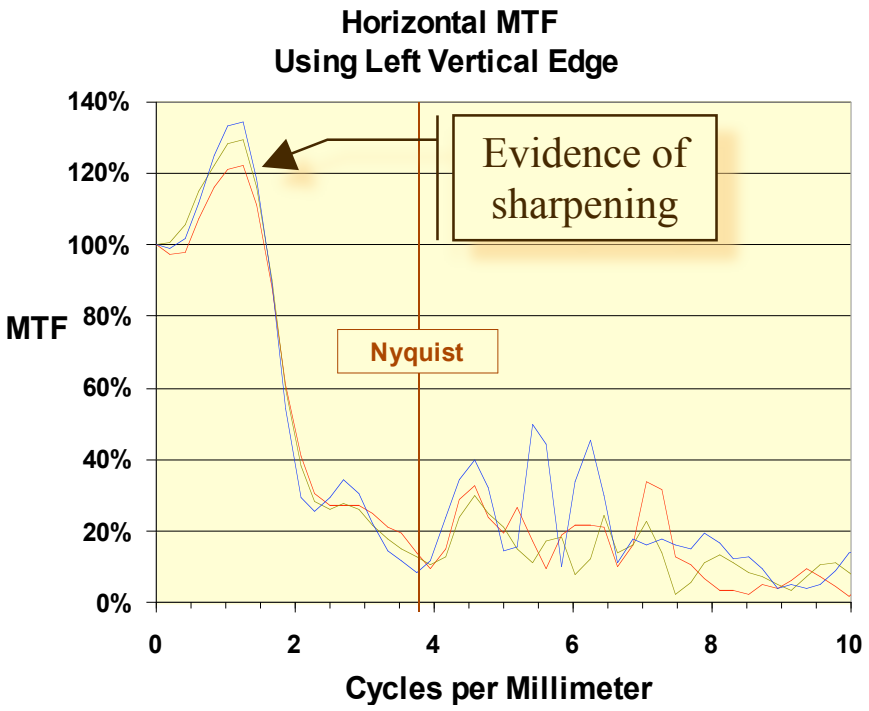
"… specifies methods for measuring and reporting the spatial resolution of electronic scanners for continuous tone photographic prints. … applies to both monochrome and colour print scanners."

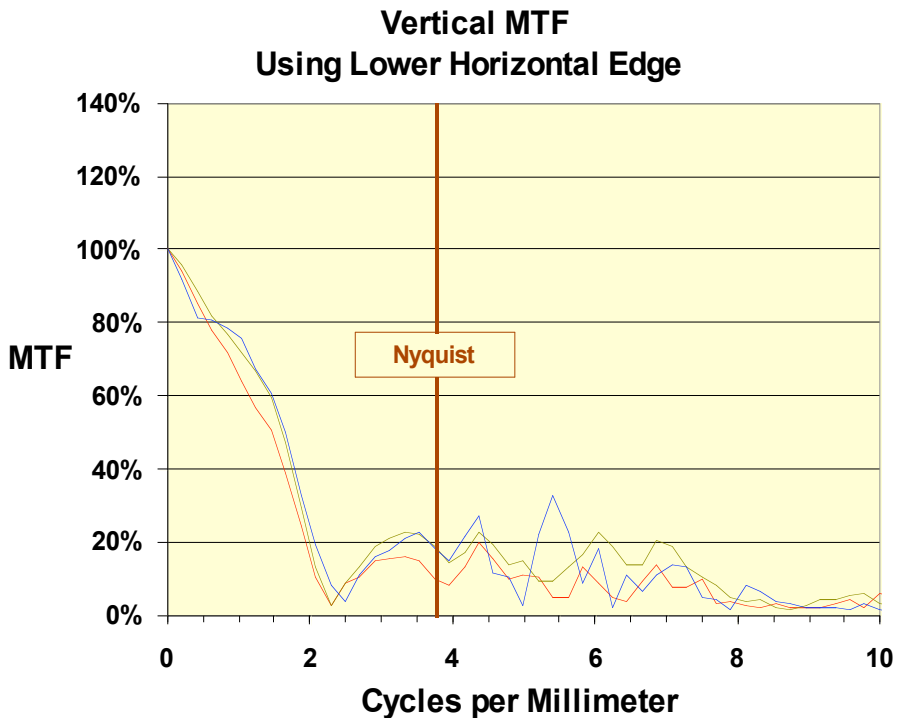
Measured Tonal Response Function (OECF) for a Moderate Quality Digital Still Camera



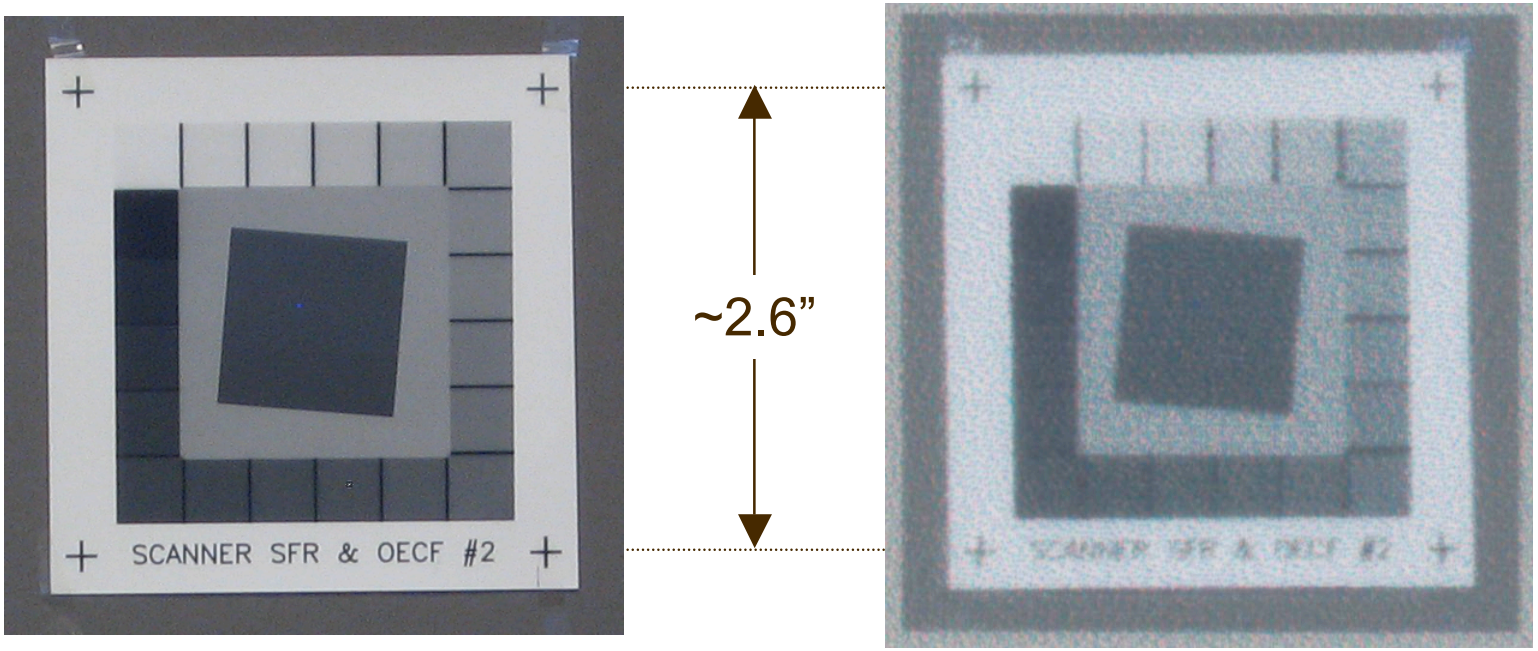
For details of *sRGB*, see http://www.w3.org/Graphics/Color/sRGB

Modulation Transfer Functions for a Moderate Quality Digital Still Camera



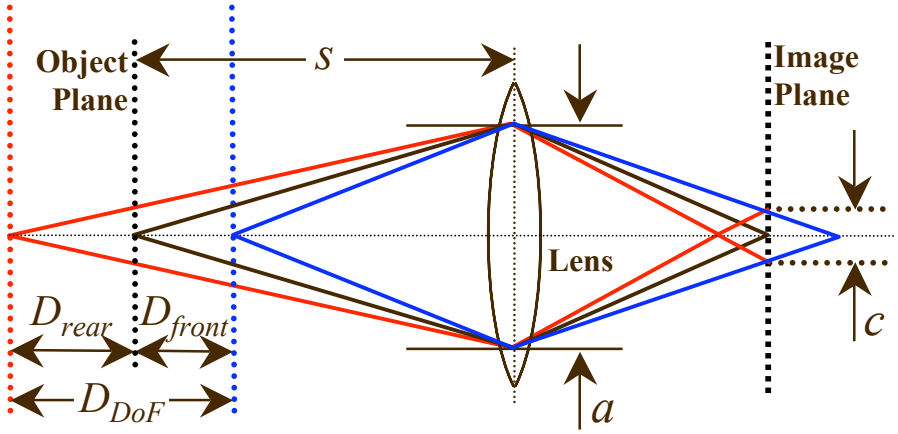


Quality Comparison of Direct Digital and Scanned Printed Photo



- Direct digital capture using moderate quality camera with optical zoom
- Same image printed with an inkjet printer using correct passport reduction ratio on glossy photo paper, highest quality setting
- Scanned at 2400 pixels/inch

Depth of Field Calculation



Since $s >> f$ and $f^2 >> cFs$

$$D_{DoF} \cong \frac{2cs^2F}{f^2}$$

Example for a digital SLR :

$f = 70mm,\ s = 1.5m,$

$F = 8,\ c = 0.016mm$

$D_{DoF} \cong 12cm$

$$D_{front} = \frac{cFs(s-f)}{f^2 + cF(s-f)}$$

$$D_{rear} = \frac{cFs(s-f)}{f^2 - cF(s-f)}$$

$$D_{DoF} = D_{front} + D_{rear}$$

D_{front} = the front focal distance, the distance from the object plane to the plane closest to the lens that is still in acceptable focus,

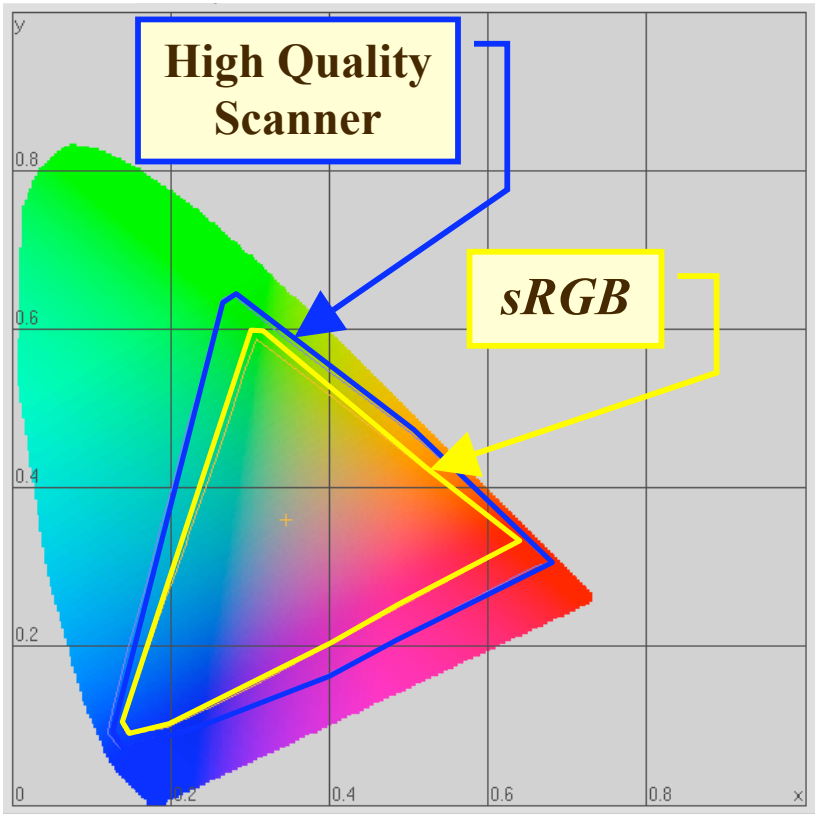
D_{rear} = the rear focal distance, the distance from the object plane to the plane farthest from the lens that is still in acceptable focus,

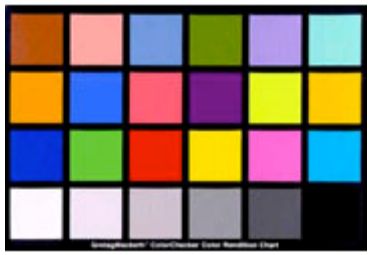
c = the diameter of the circle of confusion,

s = the object distance, the distance from the lens to the object plane, and

$F = f/a$ is the F-stop, the lens focal length f divided by the effective lens aperture a

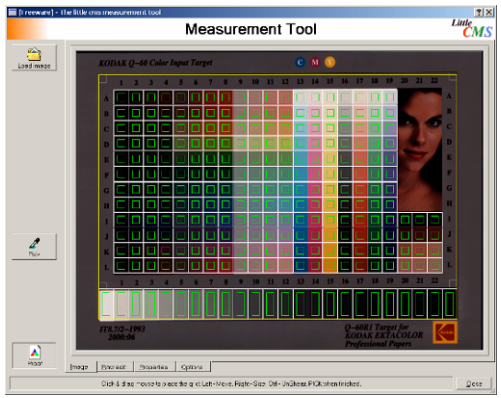
Gamuts for *sRGB* and a Scanner





Macbeth ColorChecker

IT8.7/2



Little CMS
http://littlecms.com/

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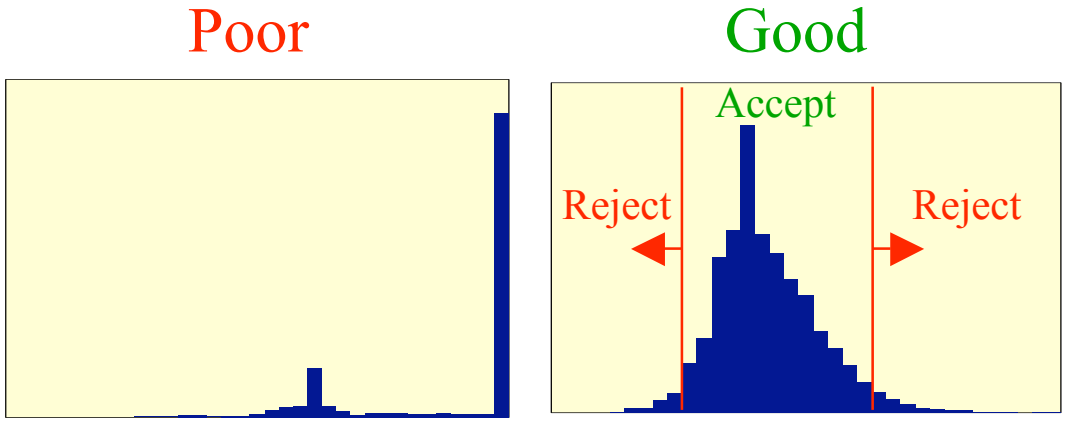
Desired Face Image Quality Metrics

- **Dynamic Range in Face** – intensity density in the facial region should be at least 7 bits of intensity variation (at least 128 unique values) in face after conversion to grayscale (ISO 19794-5 7.4.2)
- **Eyes Closed/Obstructed** – measured as a percentage, value should reflect degree of obstruction of eyes due to eyeglass rims, tint, or glare, bangs, eye patches, head clothing, or eyes closed (e.g., 100% obstructed if both eyes are closed; 50% obstructed if one eye is obstructed) (7.2.3, 7.2.11)
- **Color Balance** – must reflect natural colors with respect to expected skin tones. This value can be affected by inappropriate white balancing or red-eye (7.3.4)
- **Lighting Uniformity on Face** – measured as a percentage, value should measure symmetry as affected by shadows or hot spots on the face (7.2.7-7.2.10)
- **Background Uniformity** – measured as a percentage, value should measure symmetry and consistency as affected by shadows on the background, textured backdrops, or extraneous objects in the background. (A.2.4.3)
- **Head Size** – Head width to image width ratio should be between 5:7 and 1:2 (8.3.4, 8.3.5, A.3.2.2)
- **Centering –** horizontal and vertical position of face (8.3.2, 8.3.3)
- **Distance Between Eyes** – measured in pixels, should be at least 90 pixels between eyes (8.4.1) and preferably 120 pixels (A.3.1.1)
- **Focus** –measures sharpness and resolution of the facial area. Depth of focus must maintain at least 2 mm per-pixel-resolution and preferably 1 mm per-pixel throughout the face. Image should not be overly sharpened. (7.3.3, A.2.5)
- **Rotation (yaw)** – value should measure deviation from frontal in degrees, compliance requirement is < ± 5° (7.2.2)
- **Tilt (roll)** – value should measure deviation from frontal in degrees, compliance requirement is < ± 5° (7.2.2)
- **Confidence in Face** – measures the confidence of the eye finding and the confidence that the object is a face
- **Brightness Exposure/ Contrast** – low score if too dark or too bright, exposure measured in RGB values–gradations in skin texture should be visible, no saturation on the face (7.3.2)

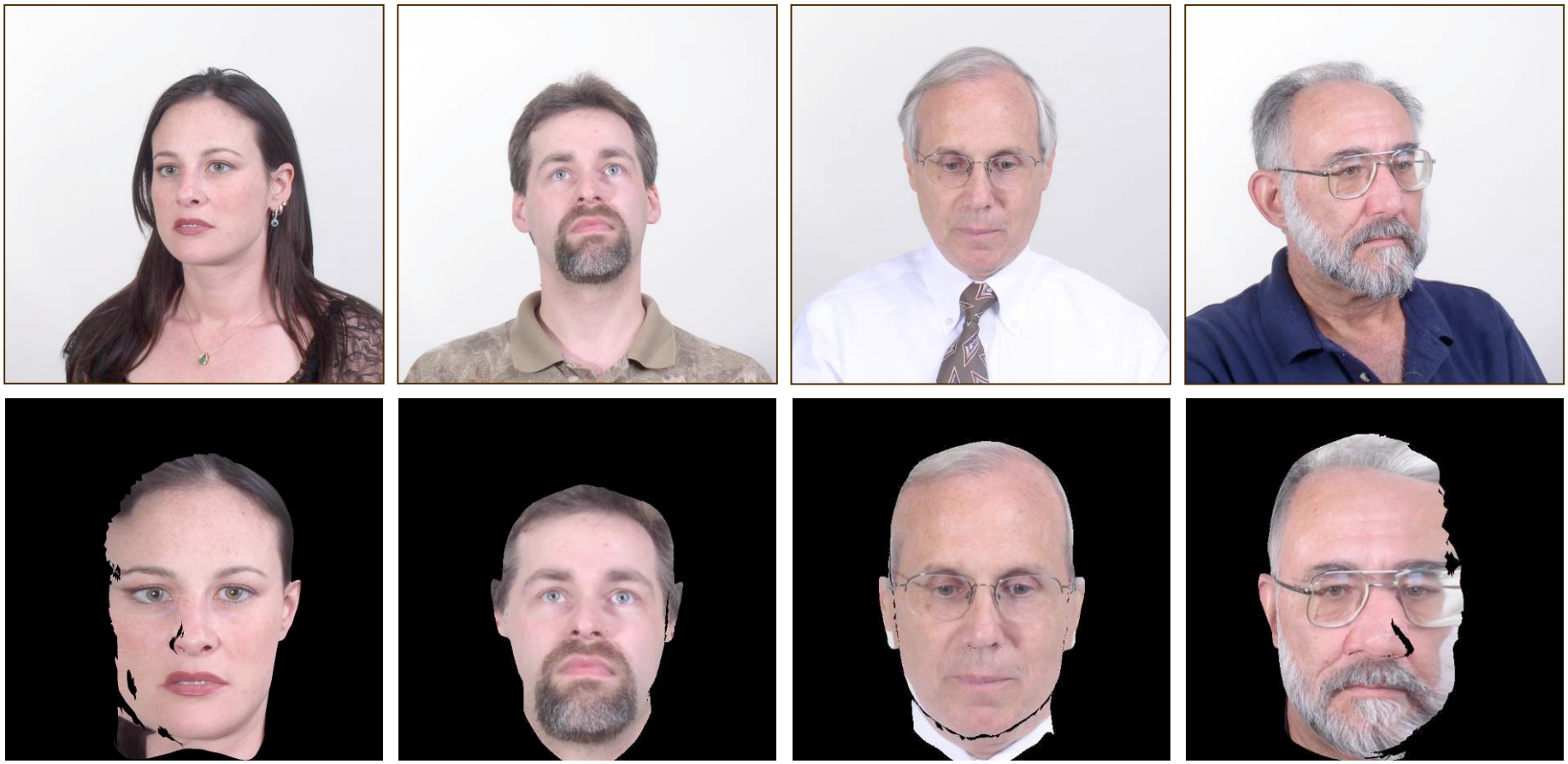
Desired Face Image Quality Metrics

- ✓ Would like well-distributed, thresholdable histograms on representative images



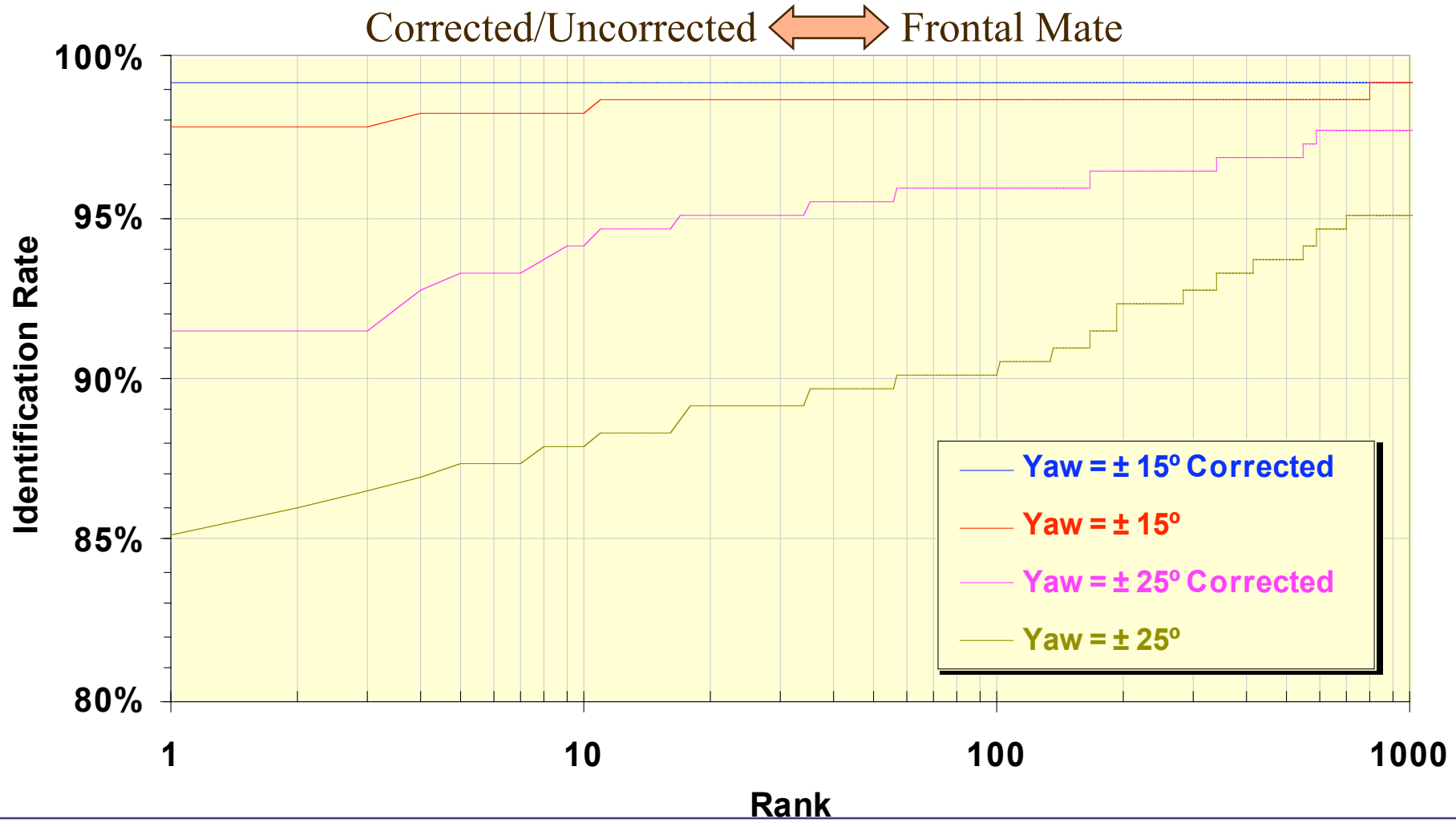
- ✓ Metrics should measure compliance with ISO 19794-5
- ✓ Desire good correlation of metrics with human perception
- ➢ At least four face image quality assessment products are commercially available

Results for Animetrics' Pose Correction Product



- Automatic, batch processing
- Estimates and corrects pitch, roll, yaw (up to 40°)
- User can input eye positions
- User may adjust minimum pose angle for corrections

Cumulative Match Characteristic for Uncorrected and Corrected Pose Angles



Receiver Operating Characteristic for Uncorrected and Corrected Pose Angles